VEHICLE EMISSIONS

Propane Gas

Results for propane gas are presented in Figures 7 and 8. In Figure 7a, the mean ozone reactivity of propane gas exhaust from the Ford propane gas vans varied from 62 percent less than for RF-A exhaust at 5,000 miles to 71 percent less at 25,000 miles. Note that, even though the NMOG emissions were higher for propane gas vehicles than for their controls on a mass basis (the plot of NMOG), the calculated ozone reactivity was less. This is because the mass emissions of NMOG from propane gas had a significant fraction of unburned fuel as propane in the exhaust. NMOG mass emissions were comprised of 86 percent propane at 5,000 miles dropping to 83 percent propane at 25,000 miles. Propane is relatively unreactive photochemically in the atmosphere, and therefore the NMOG emissions had a lower ozone reactivity than the emissions from the control vans on RF-A gasoline.

The measured emissions of NO_x, NMOG, and CO in Figures 7a and 7b all show a relatively constant level with mileage. Note one extremely high value for CO emissions at about 20,000 miles. This test was performed within days of work on the ADP fuel system to correct problems the system was experiencing in receiving a signal from the engine. It is not known if this maintenance work contributed to the high CO emissions.

The mean relative emissions of CO, NO_x, and NMOG in Figure 7 all show a downward trend with mileage. That is, the emission levels for propane gas vans became increasingly smaller than from the control vans. This trend reflects near constancy of emission levels for propane gas over mileage, while the control vans on gasoline exhibited degradation of emissions as mileage increased. The extent of variability in the data is evident from the width of the 95-percent confidence intervals.

Relative emission levels of air toxics and greenhouse gases did not show much variation with mileage compared to the exhaust from the control vans. Levels of acetaldehyde, benzene, and 1,3-butadiene were significantly less in exhaust from propane gas than in exhaust from the control vans. The level of formaldehyde in propane gas exhaust varied from about 55 percent less at 5,000 miles to 45 percent less at 25,000 miles compared to RF-A gasoline exhaust, but variability in the data precludes establishing a difference in mean emissions with 95 percent statistical confidence. Note that the scale for the plot of percent difference for methane extends from -100 to 300 percent, a change from the scale for CNG vehicles of -100 to 8,000 percent in Figures 4d, 5d, and 6d. The scale to 300 percent is used for propane gas, RFG, and M-85. Nitrous oxide emissions were measured over a small mileage interval and were highly variable.

Results for the Chevrolet propane gas vans are presented in Figure 8. NMOG mass emissions were higher than for gasoline. Propane comprised about 83 percent of the NMOG mass. Note the large spread in measured emissions of NMOG at about 25,000 miles from one propane gas van. Although the NMOG emissions from propane gas were higher than from gasoline, the ozone reactivity was less, averaging about 58 percent less at 5,000 miles and 76 percent less at 25,000 miles.

Carbon monoxide levels ranged from 49 to 58 percent less than for gasoline over mileage. Note the high exhaust level of CO at about 13,000 miles for one propane gas van.

Emission levels of the air toxics from propane gas vans were about constant over mileage or exhibited decreasing trends. In contrast to the constancy of the emission levels plotted in units of g/mi, the relative difference in emissions of the air toxics formaldehyde and acetaldehyde shows a downward trend with increasing mileage. This trend is the result of increasing emission levels of these two compounds in

the exhaust of the control vans. A similar result exists for 1,3-butadiene and benzene, but it is not apparent in the plots due to the low levels of these compounds in propane gas exhaust and the scale of the plots.

Emission levels of the two greenhouse gases methane and carbon dioxide were constant over mileage. The large uncertainty band for relative methane emissions and the tight uncertainty band for relative emissions of carbon dioxide reflect two factors: the small differences in emission levels for each of these compounds compared to their controls, combined with low levels for methane and high levels for carbon dioxide with respect to measurement capabilities. Relative differences in emission levels of nitrous oxide are not plotted because of the limited data set for the control vans.

It is important to remember that the Chevrolet vans were equipped with heavy-duty engines that had been certified originally to heavy-duty exhaust emission standards. As for the Chevrolet CNG vans, the AFE fuel system components were replaced in September 1993 in an attempt to correct operational problems. The AFE components were replaced at 14,000 to 16,000 miles (see Table C-3). No significant change in emissions was found as a result.

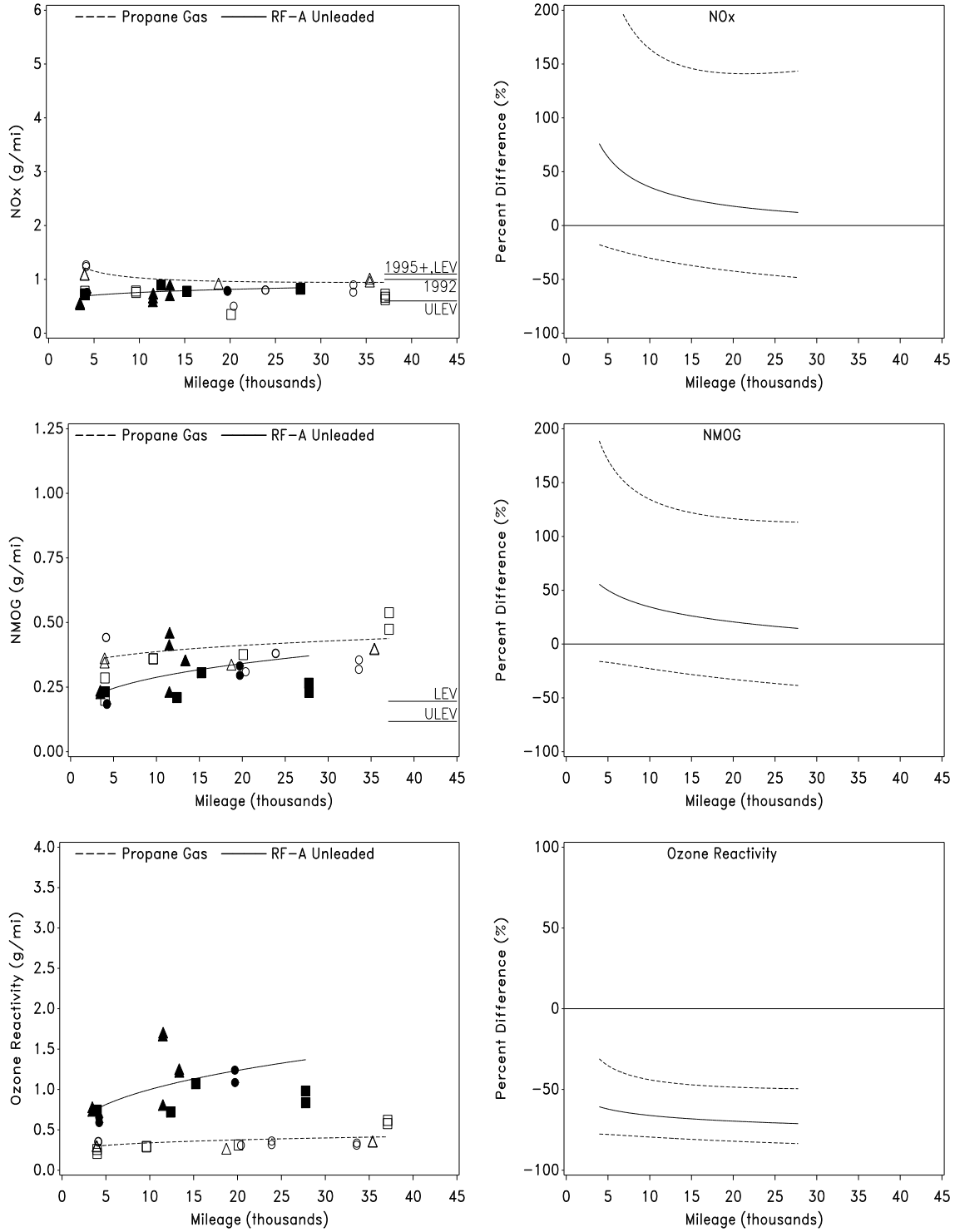

Figure 7a. Estimated Mean Levels of NO_x, NMOG, and Ozone Reactivity of Exhaust Overlaid on Individual Test Results for Ford Propane Gas and Control Vehicles; Mean Percent Difference in Emission Levels from Alternative Fuel Vehicles Compared with Control Vehicles, Along with 95 Percent Confidence Bounds

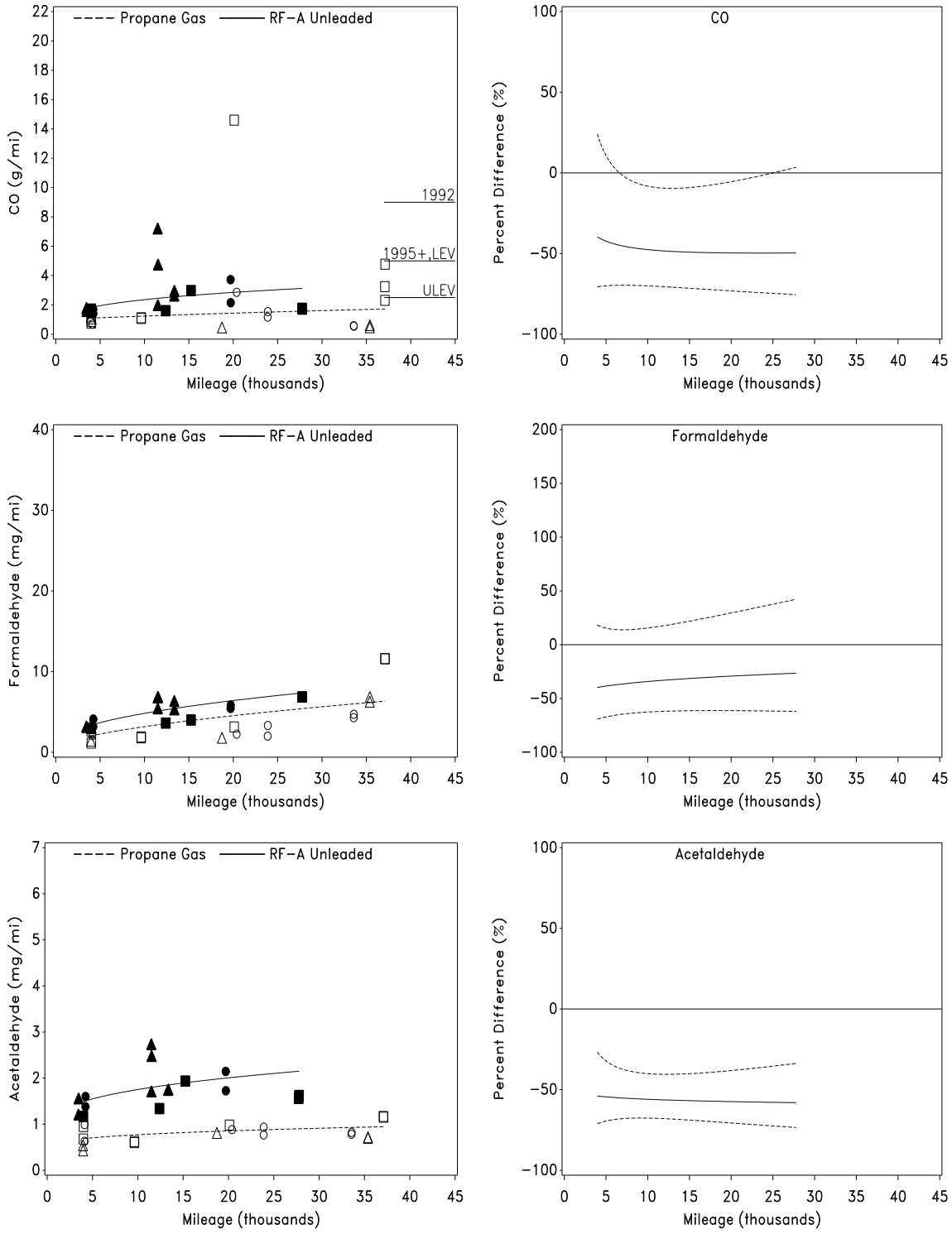

Figure 7b. Estimated Mean Levels of Carbon Monoxide, Formaldehyde, and Acetaldehyde Overlaid on Individual Test Results for Ford Propane Gas and Control Vehicles; Mean Percent Difference in Emission Levels from Alternative Fuel Vehicles Compared with Control Vehicles, Along with 95 Percent Confidence Bounds

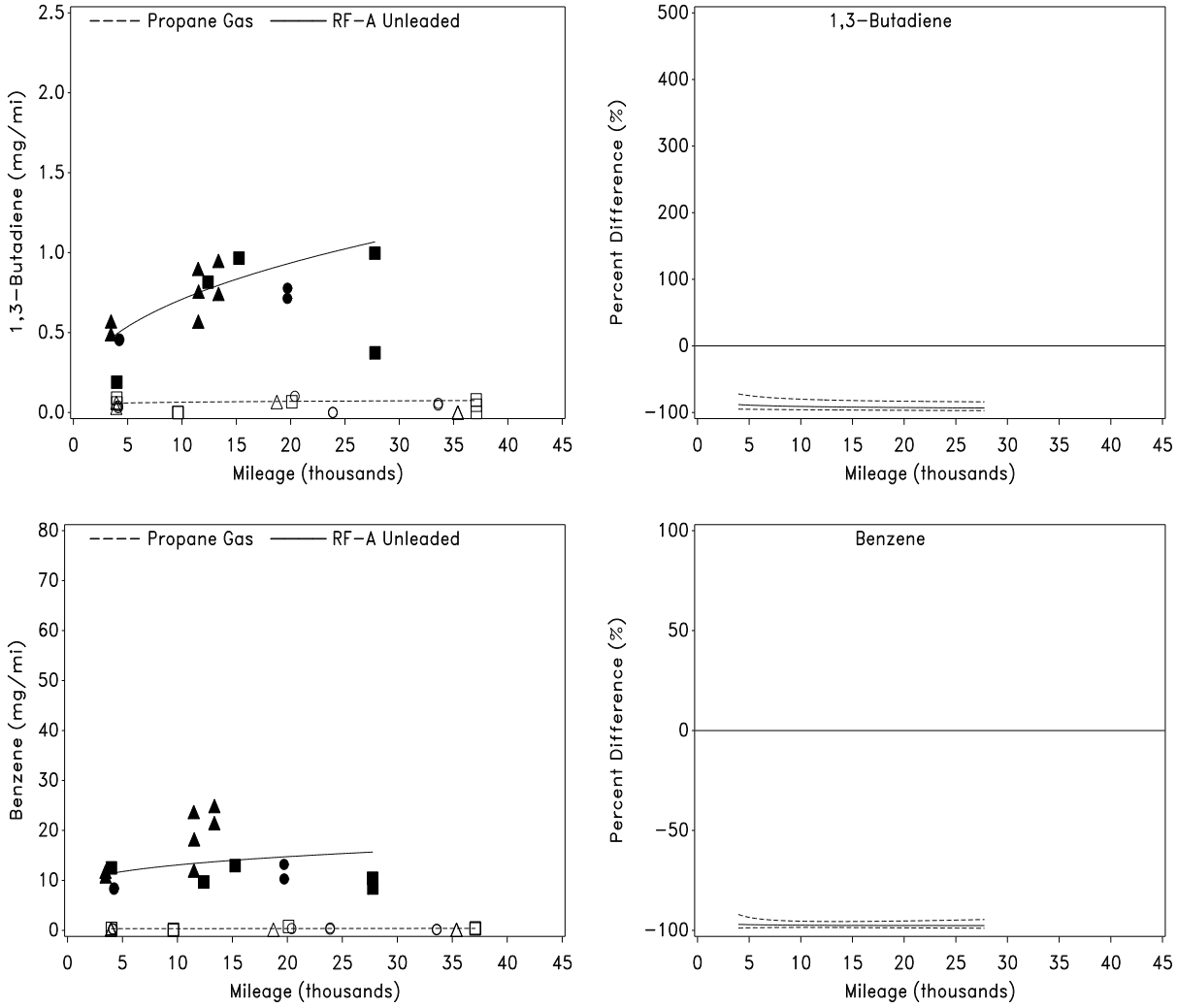

Figure 7c. Estimated Mean Levels of 1,3-Butadiene and Benzene Overlaid on Individual Test Results for Ford Propane Gas and Control Vehicles; Mean Percent Difference in Emission Levels from Alternative Fuel Vehicles Compared with Control Vehicles, Along with 95 Percent Confidence Bounds

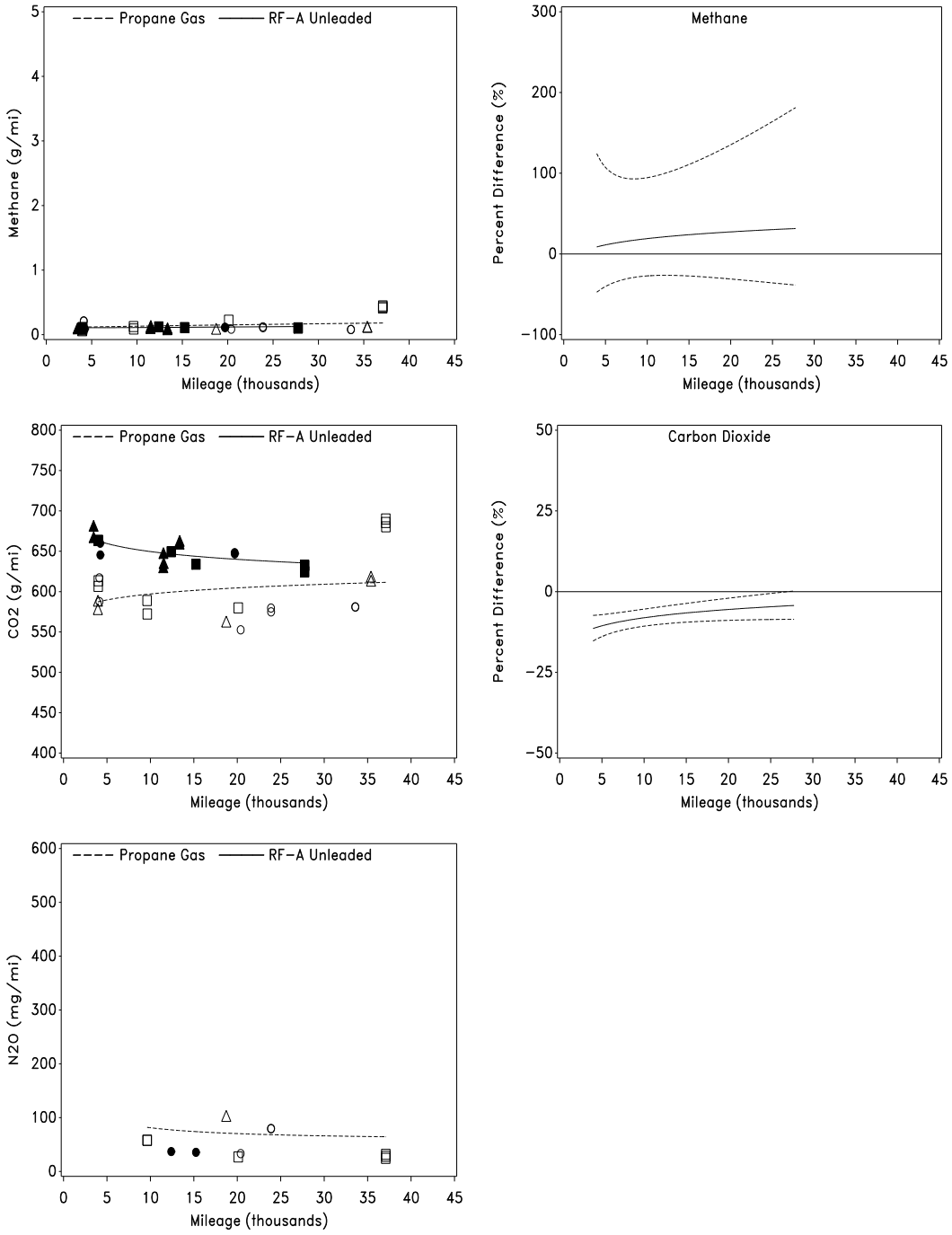

Figure 7d. Estimated Mean Levels of Methane, Carbon Dioxide, and Nitrous Oxide Overlaid on Individual Test Results for Ford Propane Gas and Control Vehicles; Mean Percent Difference in Emission Levels from Alternative Fuel Vehicles Compared with Control Vehicles, Along with 95 Percent Confidence Bounds

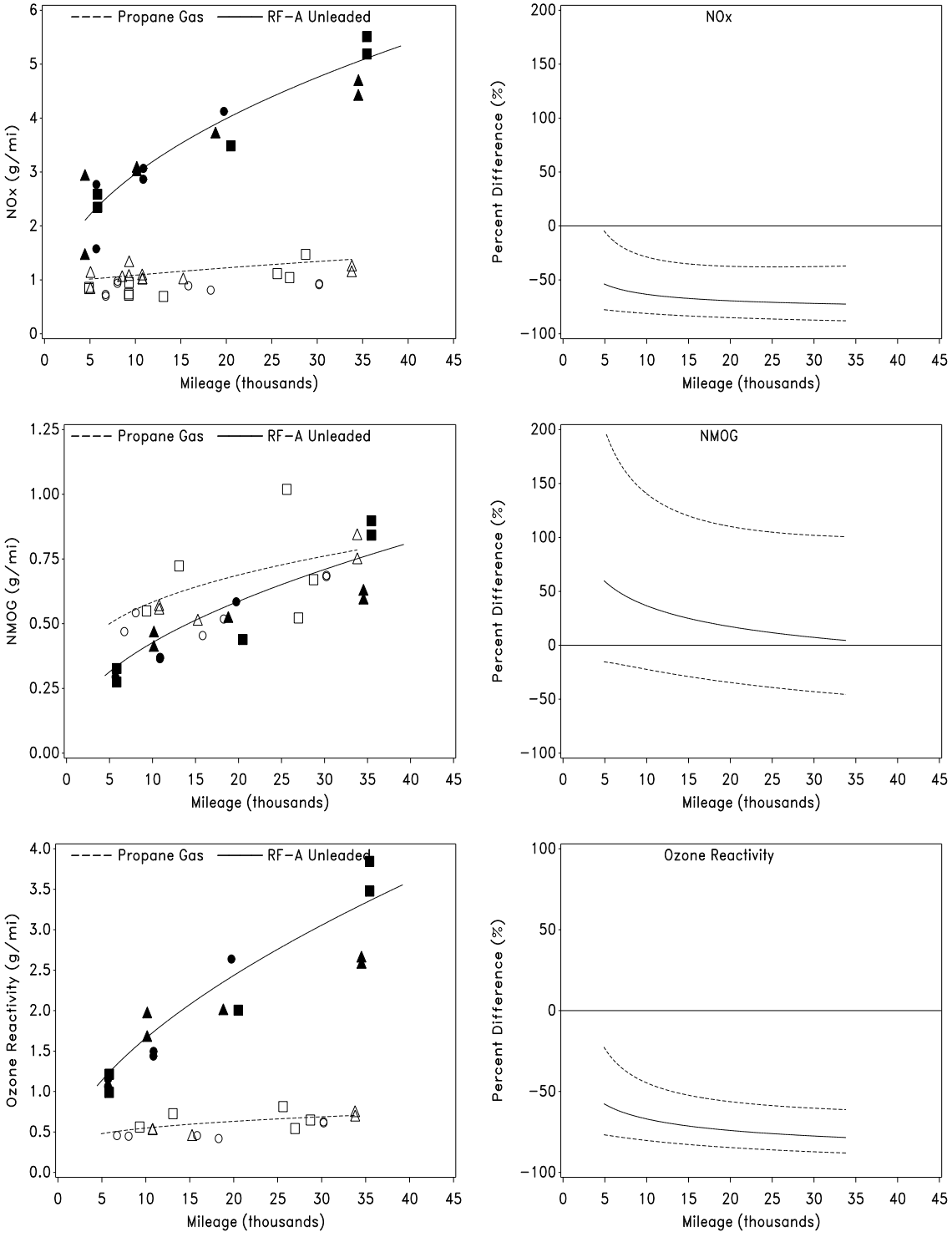

Figure 8a. Estimated Mean Levels of NO_x, NMOG, and Ozone Reactivity of Exhaust Overlaid on Individual Test Results for Chevrolet Propane Gas and Control Vehicles; Mean Percent Difference in Emission Levels from Alternative Fuel Vehicles Compared with Control Vehicles, Along with 95 Percent Confidence Bounds

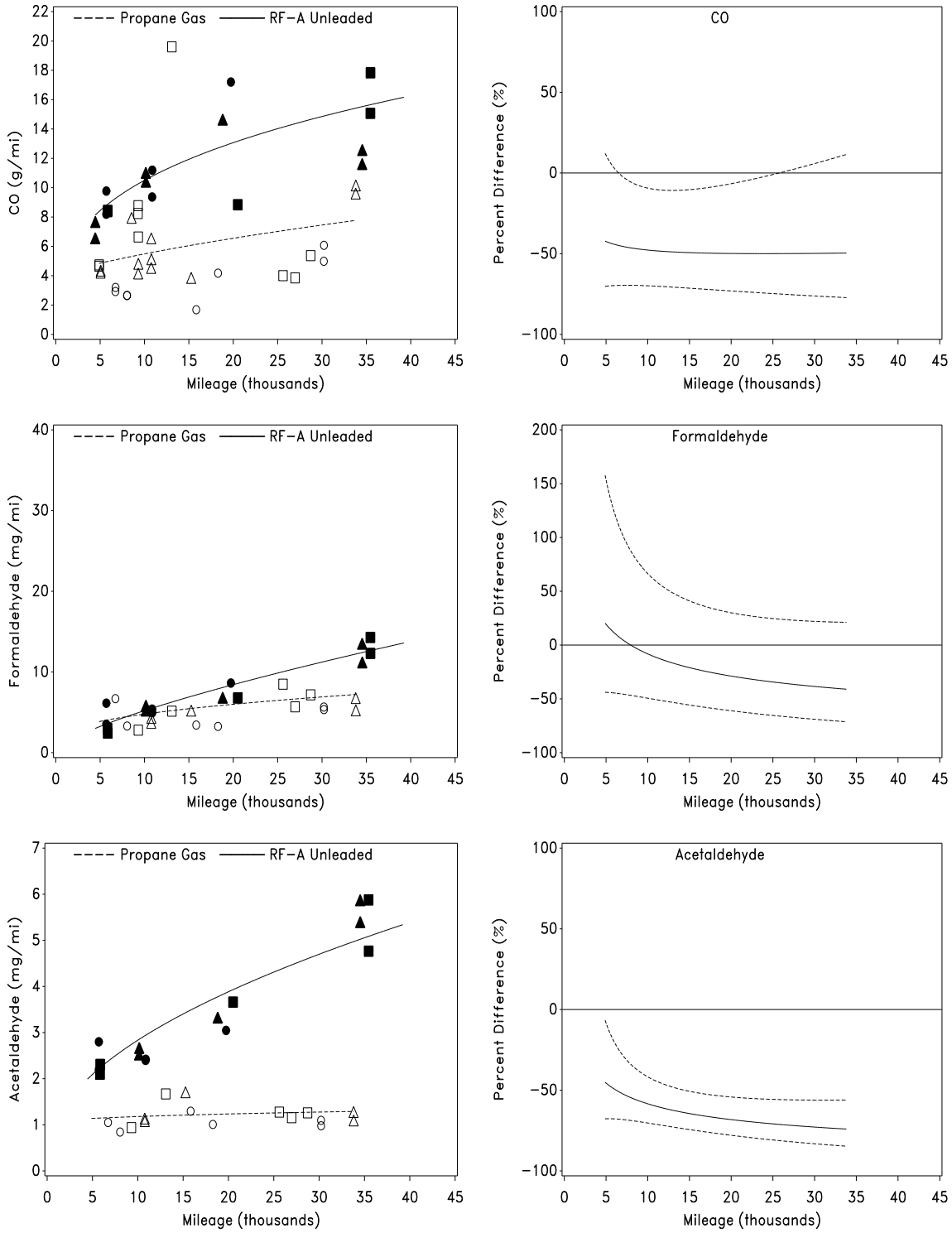

Figure 8b. Estimated Mean Levels of Carbon Monoxide, Formaldehyde, and Acetaldehyde Overlaid on Individual Test Results for Chevrolet Propane Gas and Control Vehicles; Mean Percent Difference in Emission Levels from Alternative Fuel Vehicles Compared with Control Vehicles, Along with 95 Percent Confidence Bounds

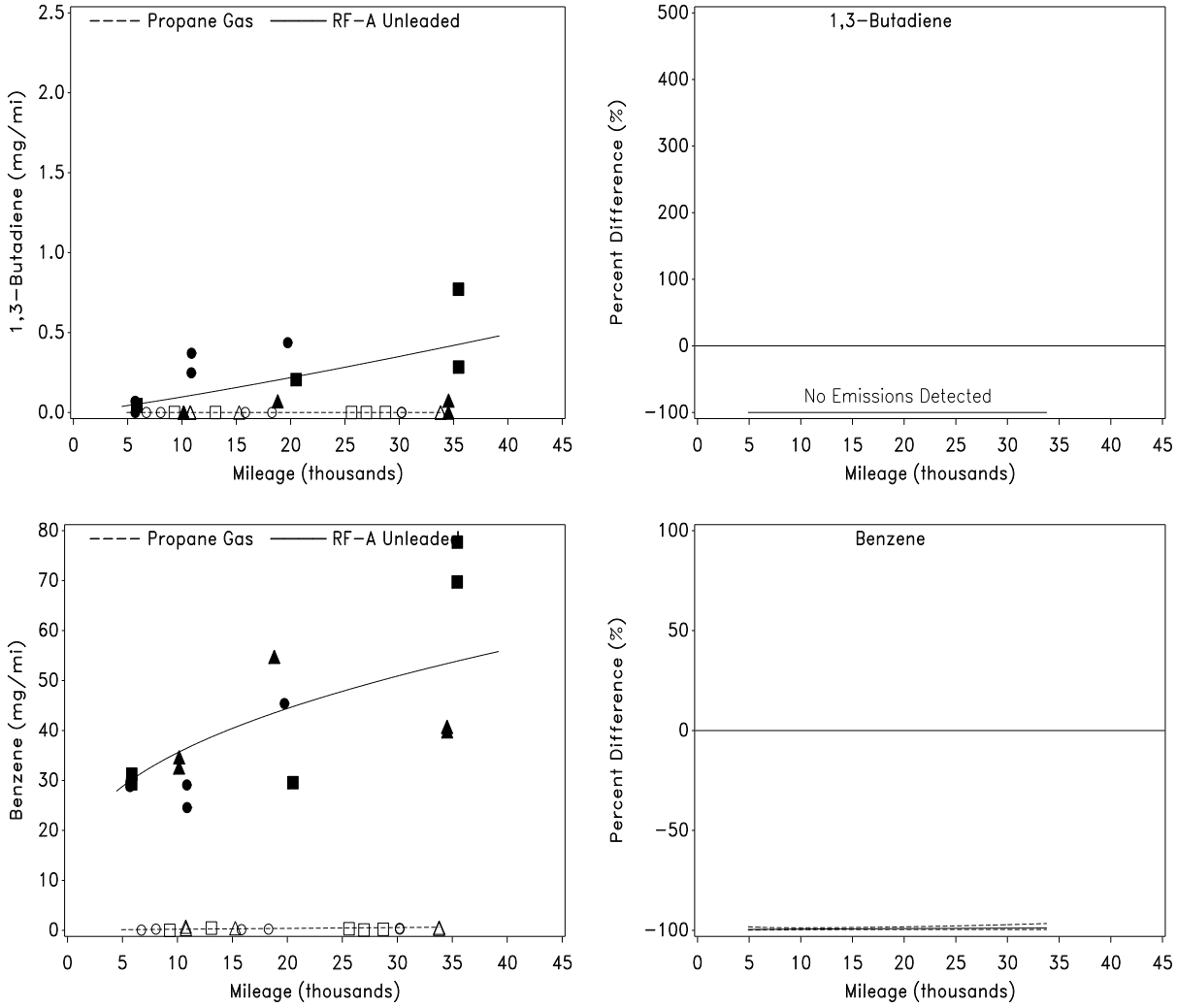

Figure 8c. Estimated Mean Levels of 1,3-Butadiene and Benzene Overlaid on Individual Test Results for Chevrolet Propane Gas and Control Vehicles; Mean Percent Difference in Emission Levels from Alternative Fuel Vehicles Compared with Control Vehicles, Along with 95 Percent Confidence Bounds

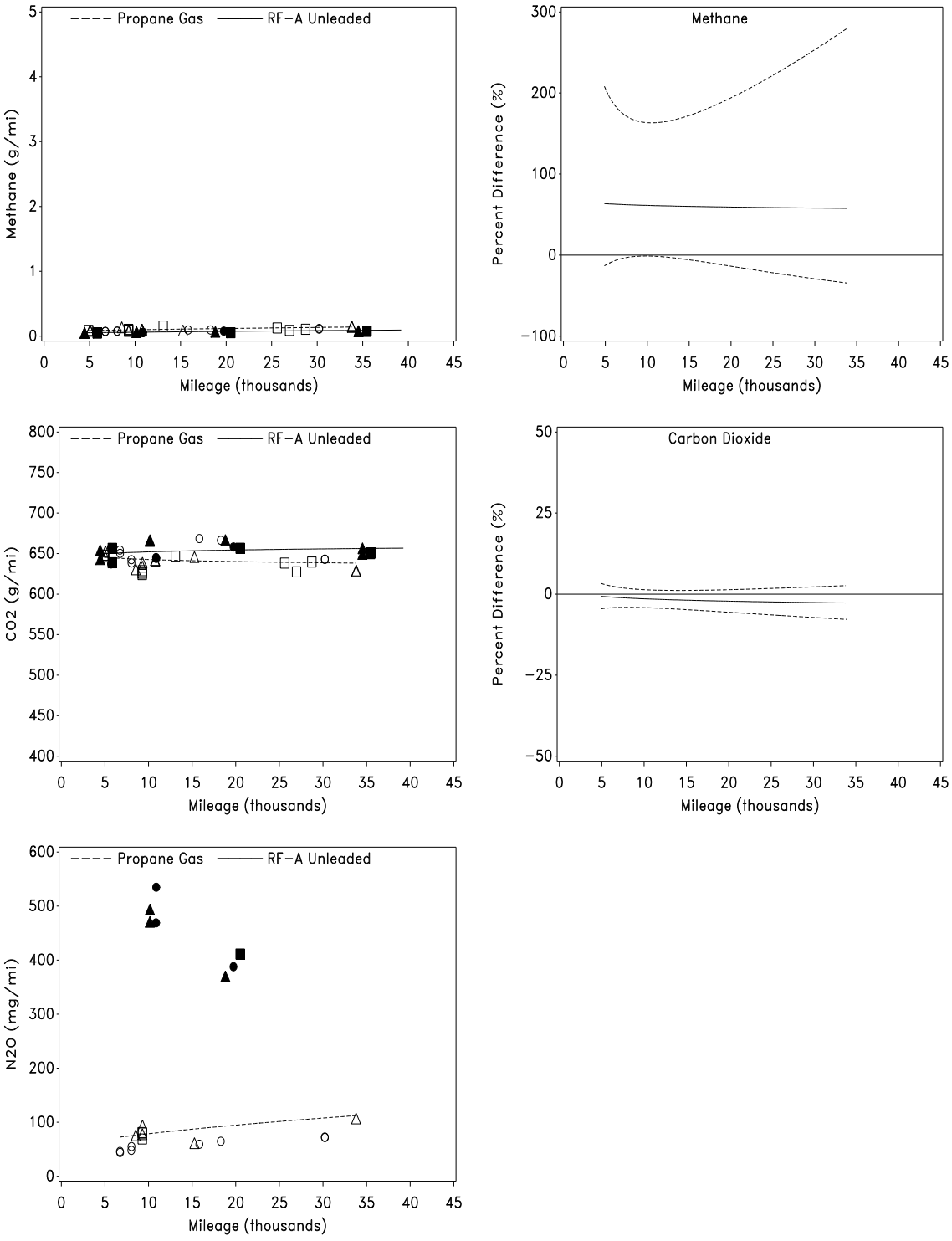

Figure 8d. Estimated Mean Levels of Methane, Carbon Dioxide, and Nitrous Oxide Overlaid on Individual Test Results for Chevrolet Propane Gas and Control Vehicles; Mean Percent Difference in Emission Levels from Alternative Fuel Vehicles Compared with Control Vehicles, Along with 95 Percent Confidence Bounds